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W. D. MOFFAT, VICE-PRESIDENT
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AVIATION AND AERONAUTICAL ENGINEERING

ALEXANDER KLEMIN, TECHNICAL EDITOR
LADISLAS D'ORCY, ASSOCIATE EDITOR
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Vol. VII September 15, 1919 No. 4

THE report of the United States Aviation Mission on its findings with regard to the status of aeronautics in Europe—an abstract of which was printed in the preceding issue of AVIATION AND AERONAUTICAL ENGINEERING, and which has been published *verbatim* in pamphlet form—is a document worth the most careful perusal of all those concerned with the future of American aeronautics and the safety of the United States.

Regarding the organization of our air forces the report comes out boldly for a unified air service and a single air department headed by a cabinet officer. In this matter the recommendations of the Aviation Mission tally in their wider lines with the provisions of the bill Senator New introduced in Congress, and are interesting mainly because they show that the axiom of "one service for one element" is making decided headway.

Among the many striking passages occurring in this report the following seems to sum up the whole crux of the problem and constitutes, so to speak, a writing on the wall·

"One of the striking features of our investigation in Europe was the unanimous belief that the use of aircraft in warfare and for national defense would continue to increase, and that in the next war, whenever it might come, aircraft would be a far more vital factor than it has been in this war. One of the greatest military authorities in Europe stated that in his opinion the first battle of the next great war would be in the air, and would very nearly decide which side would win, in that the side winning in the air would immediately have access to all of its enemy's sources of supply and production and would quickly cripple them by air raids upon enormous scale"

The report goes on to say that it is generally realized that owing to the delicate nature, the rapid depreciation and constant obsolescence of aircraft equipment the expense involved in maintaining an air force and manufacturing facilities adequate for purposes of national defense are almost prohibitive in peace times. It is evident, continues the report, that the most economical way to develop a strong air service for national defense is to encourage by every means possible the use of aircraft for commercial purposes, and thereby build up a commercial fleet at relatively small expense to the government, which would effectively supplement its strictly military equipment in time of need.

It is pointed out that America's experience during the war has proven conclusively that aircraft equipment and personnel, and particularly production facilities and technical personnel, cannot be obtained upon short notice, but only by long and continued experience and at great expense. Therefore, unless prompt and suitable action is taken to conserve the American aircraft industry built up during the war, nine tenths of which has been liquidated, the United States will hopelessly be outstripped in aeronautics by more progressive nations.

This is a viewpoint which AVIATION AND AERONAUTICAL ENGINEERING has steadfastly defended since the signing of the Armistice and it is to be hoped that since the importance of a merchant air force for national defense comes to be realized in official quarters Congress will not turn a deaf ear on the advocates of this economical means for preserving America's integrity

Airplane Fittings

It is somewhat surprising that after all these years of design, the question of airplane fittings should still offer so many difficult and interesting points.

For small machines, there seems to be no doubt that low-carbon steel of ordinary variety is perfectly satisfactory, and that attempts to lighten up by using alloyed steels are futile To utilize the full strength of alloyed steel on a small machine, the fittings would have to be of paper thickness without the necessary local strength required in the mere handling and assembly of a machine.

When it comes to larger machines, however, both opinion and practice vary to a great extent For experimental work on the first machine of a series, the use of low-carbon steel is particularly handy. It can be bent and otherwise worked by hand without any difficulty.

For a complex fitting where a drop-forging or an aluminum bronze casting might finally be most useful for production, a low-carbon steel can be used, and dip-brazing or welding take care of the most difficult joints.

But in the large machine the weight of the fittings can be lightened up by the use of alloy steel. Here, however, the process of construction becomes very complex. The steel generally has to be annealed on its arrival from the factory or otherwise it is impossible to work it satisfactorily. If brazing cannot be avoided, the process of subsequent heat-treatment offers complex technical problems. Drop-forgings in the large machine can be made to have a very great strength, but are very expensive. The supply of alloy steel is always uncertain. Manufacturers find many difficulties due to these causes, and this is a problem to which engineers, steel manufacturers and metallurgists must devote considerable time before further progress can be realized.

Predicting the Performance of an Airplane

By Lt.-Col. V. E. Clark, Air Service

The curves shown herewith were prepared to provide a means for quickly estimating the absolute ceiling, and the climb and maximum and minimum horizontal speeds of a given airplane at any working altitude. To enter the charts it is necessary to have values for the total weight of the airplane, the area of its main planes, and the power of its engine at sea level—only.

Such curves are, it must be remembered, necessarily intended for very rough approximations only—to be used, for instance, in making rough comparisons between machines of similar general characteristics. It will be realized that, owing to the many variables involved mentioned hereinafter, it would be

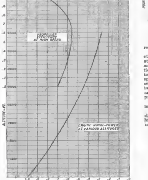

Fig 1

impossible to draw curves susceptible of such rapid use as those which could be depended upon for accuracy. Readers are warned that the use of these curves is not intended to supplant the more accurate, albeit slower and more expensive, method of making wind tunnel tests on models, making empirical corrections for full scale, and summarizing the parasite resistance, thereby obtaining data necessary to plot performance graphs. These are merely "handy" curves, which, it is hoped, may prove useful at times.

The curves for stalling speeds (Fig 3) and for ceiling (Fig 2) may be depended upon for fair accuracy. The curves for speed range cannot be depended upon for accuracy, although the curves for climb should be more accurate because the parasite resistance factor is not, for the rate of climb, so important, in comparison to the total weight, as in the case of high speed

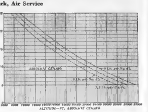

Fig 2

The speed range curves are not dependable for accuracy for reasons as follows:

The maximum horizontal speed at any altitude is that speed at which the thrust given by the propeller driven by the engine at full throttle—is equivalent to the total resistance of the airplane whose flight attitude is then such as to give sustentation (at the given speed) equal to its total weight. Referring to the commonly used power and performance curves, it is the speed where the two curves (both plotted against speed) intersect. (1) Power required to give thrust necessary to overcome total resistance (augmentation by slip stream being considered) under conditions noted above, and (2) power delivered by propeller driven by engine at full throttle.

Hence the considerations upon which the speed range and maximum horizontal speed at any altitude depend are:

I The *aerodynamic efficiency* of the airplane, in other words, its lift-drag ratio, as a complete unit, for the flight attitude at high speed. This flight attitude varies, of course, with change in altitude.

This factor is affected by the characteristics of the main

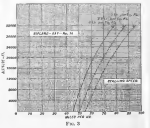

Fig. 3

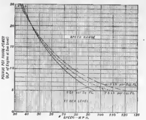

Fig 4

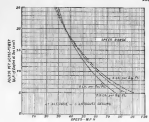

Fig. 6

sustaining surface or surfaces (section, plan form, disposition, etc.) and by the provisions which it is possible to make in the design to minimize parasite resistance (resistance of fuselage, exposed structural bracing, tail, landing gear, etc.), by streamlining and "cleaning up" the ship.

The parasite resistance factors vary widely, not only with change in the size of the airplane, but also with varying arrangements in different types. Airplanes with more than one fuselage or nacelle can scarcely be classed with the single-engine, single-fuselage tractor type in plotting speed curves. (Note example 2.)

The curves shown were drawn for the single-engine tractor biplane over-land type. The *L/D* curves for the DeH-4 rigged with cable (faired), with full military equipment installed (corrected for full scale and slip stream) were used.

II The other factor affecting high speed is: The ratio between (1) power delivered by propeller, and (2) weight of airplane, loaded.

As a general rule, increase in total weight without corresponding increase in power reduces the possible horizontal high speed. Increased weight necessitates, for sustentation, either increase in area of main planes, or, if the area remains the same, increased angle of incidence. Ordinarily, either means increase in drag of main planes, and thus, for the same power, reduction in speed.

This rule is susceptible of general application. There are possible, however, certain conditions under which it may not apply. For instance, an airplane may be conceived of such great power, of such low weight, and of such light wing loading that, near sea level, in the high speed condition, the angle of attack is so low as to cause the airplane to operate on the *left limb* of the curve of wing drag as plotted against incidence. In such a case, the addition of weight would, in order to obtain sustentation in the high speed condition, necessitate a higher lift coefficient, which would mean a higher angle of attack, and, in the extreme case in question, would reduce the wing drag coefficient, instead of increasing it.

(1) The power developed by the propeller by way of thrust depends upon:

(a) *The power of engine at the given altitude under full throttle*, which again depends upon its power at sea level, the rate of loss of power with height (and consequent loss of oxygen and compression), and the torque resistance of the propeller affecting speed of revolution and thus the power.

The curve of power (Fig 1) represents an average for engines of the water-cooled type, with modern practice com-

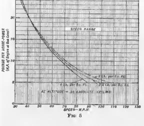

Fig 5

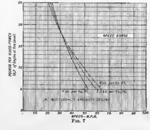

Fig. 7

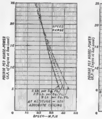

Fig 8

Fig 9

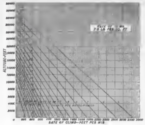

Fig 11

pressian ratias and volumetric efficiency It is assumed that the altitude control for the carburetor is effective at all altitudes shown. It is also assumed that the decrease in power is normal; that no device is used such as supercharger, extra oxygen, or special fuel

(b) *The efficiency of the propeller* at the maximum speed of airplane and the speed of revolution under full throttle. The curves of propeller efficiency can be made to vary widely and propeller design is a factor which, more than any other of the many variables, makes it impossible to draw speed curves accurate as applied to varying conditions.

The curve of propeller efficiency (at high speeds) assumed (Fig 1) was based upon assumptions entirely arbitrary.

The curves for climb, absolute ceiling and stalling speeds were drawn for the same general type of airplane as that mentioned above. Variation in general arrangement should affect these attributes less than high speed. The stalling speed especially is affected little by change in type, except in the case of the monoplane or triplane.

It must be remembered that these curves also are only intended to give a very rough approximation of the performance, as these performances are also affected materially by the design of the propeller, wing characteristics, and parasite resistance factors.

Criterion for Rate of Climb

$V \sin\theta = (T\text{-}D)\, V.1/W$
V = air speed along flight path
θ = angle of flight path to horizon.
W = total weight of airplane.
T = Thrust of propeller.
D = total head resistance of airplane operating at the angle of incidence giving the best rate of climb (usually about 8 deg)

$V \sin\theta$ = vertical component of the air speed or, in other words, the rate of vertical climb.

It appears then that the rate of climb varies inversely as the weight, and directly as the difference between TV and DV. TV = the power supplied by the propeller DV = that portion of this power that is consumed in overcoming the total head resistance of the airplane at the climbing speed.

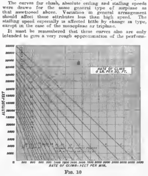

Fig. 10

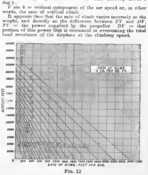

Fig. 12

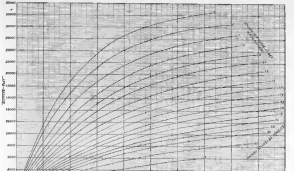

Fig 13

In plotting the curves for climb, it was assumed that the same propeller is employed as for the high speed tests and that this propeller was designed primarily as is indicated in Fig 1, to give its maximum efficiency for the *high speed condition* at about .65 of the absolute ceiling (Lower pitch would give better climb but less speed) The efficiency of such a propeller at climbing speeds is usually about 65 per cent near sea level and, as the difference between high speed and best climbing speed diminishes with altitude, the efficiency for the climbing condition increases gradually with altitude In this connection, it should also be noted that, owing to increased torque resistance of propeller at climbing speeds, the speed of revolution and hence the power of the engine is less at climbing speeds than at high speeds

It will be noted that the curves of rate of climb plotted against altitude are all straight lines. There is no fundamental reason for this, as, here again, varying kinds of power—altitude and propeller efficiency curves influence the rate of climb curves.

Method of Using Curves

The method of using these curves is very simple and can best be demonstrated by a numerical example

Example I

A single-engine, single-fuselage, overland tractor biplane weighs, with load, 4322 lb It is equipped with an engine of 400 hp, and the net effective area of its main sustaining surfaces is 490 sq ft.

Its surface loading is then 8.84 lb /sq ft. and its power loading is 10.8 lb /hp

Interpolation and extrapolation among curves are necessary.

From Fig. 2, absolute ceiling = 20,000 ft

TABLE I

1 Altitude f(abs. ceil.)	2 Altitude ft.	3 Stalling speed m.p.h. Fig. 3	4 Speed range m.p.h. Figs. 4, 5, 6, 7, 8 and 9	5 High speed m.p.h. Adding 4 to 3
0	0	54	73	127 0
250	5 000	58	67	126 0
500	10 000	64	60	124 0
750	15,000	68 5	48	115 5
875	17 500	72 5	35.5	108 0
1 000	20 000	75 0	0 5	88 0

TABLE II—CLIMB

Altitude ft.	Rate of climb ft /min. Figs. 11 and 10	Time to climb minutes Figs. 14 and 10
0	1,188	0
5,000	850	5 08
10,000	570	12 20
15,000	290	24 70
20,000	0	

From Figs. 12 and 13 service ceiling (rate of climb = 100 ft /min) = 18,150 ft and from Figs. 14 and 15, time to climb to s.c = 42 min.

Figure 18, then, shows the performance, predicted from these curves, of the machine selected as an example. This figure should serve as a typical chart for presenting estimates of performance at various altitudes

Example II

It is thought that engineers may make use of the curves shown for predicting roughly the performances of airplanes of types different from the single-engine tractor biplane in

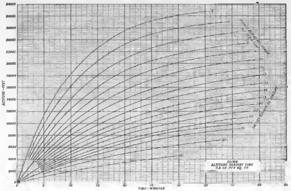

Fig. 14

general arrangement, by correcting for the resistance factors.

The following method is suggested:

First. Pick out the speed at sea level as though the machine under consideration were of the same type as that used for the curves.

Second. Use the formula

$dP = .002666V^3dK_x$

where V = speed in m.p.h. as obtained from the curves shown

dK_x = difference in total resistance coefficient at the angle of incidence for given speed between the machine considered and the type for which the curves were drawn—the total area of main sustaining surfaces considered equal. This factor may be roughly estimated by consulting the values of resistance coefficients of various bodies, such as nacelles, etc. The units are miles per hour, square feet, and pounds.

dP = Difference in propeller horsepower required at given speed.

We thus obtain a new hypothetical value for the horsepower which we divide into the total weight, and, consulting the charts, obtain corrected values for performance.

The method is, of course, very rough, but it is quick and handy.

Example

Suppose we have a biplane in general geometrically similar to the DeH-4, but of larger scale throughout and with two nacelles inclosing engines in addition to the central fuselage. We have added the resistance of these two nacelles.

Suppose. Total horsepower of the engines = 800
Total weight = 12,000 lb
Total area of main sustaining surfaces = 1,370 sq. ft.

Then:
Wt./power = 15 lb/hp
Surface loading = 8.75 lb./sq. ft.

From curves (Fig. 3) we get 53.5 m.p.h. slow speed at sea level.

Climb and Ceiling

Assuming speed for best climb at sea level = 53.5 (stalling speed) + 16.5 = 70 m.p.h.

The resistance coefficient of the two nacelles which have been added is $= 2K''A$,

where A = area in sq. ft. of maximum cross section.

K'' = constant depending on form (same units as above).

Suppose $A = 11$
$K'' = .0009$.

Then $dK_x = 2 \times .0009 \times 11 = .0198$

For climb $dP = .002666 \times .0198 \times V^3$
$= .002666 \times .0198 \times (70)^3$
$= 18.04$ hp

With assumed propeller efficiency = 66 per cent additional engine power (at climbing speed near sea level) to overcome resistance of two nacelles

$$= \frac{18.04}{.66} = 27.4 \text{ hp}$$

For use with our climb and ceiling curves we now have a hypothetical horsepower of

$$800 - 27.4 = 772.6$$

and a hypothetical power loading of

$$\frac{12,000}{772.6} = 15.53 \text{ lb./hp.}$$

Surface loading = 8.75 lb./sq. ft.
Absolute ceiling (Fig. 2) = 14,800 ft.

High Speed

From Fig. 4 (15 lb./hp. for first approximation), we get 57.5 m.p.h. speed range.

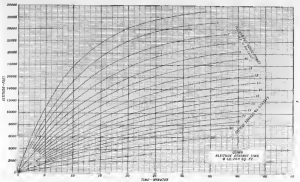

Fig. 15

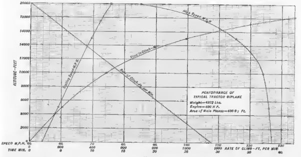

Fig. 16

$53.5 + 57.5 = 111$ m.p.h. high speed at sea level (first approximation)

$$dP = .002666 \times .0198 \times V^3 = .002666 \times .0198 \times (111)^3 = 72.2$$

With assumed propeller efficiency $= .78$, additional engine power to overcome resistance of two nacelles $= \frac{72.2}{.78} = 92.6$ hp.

For use with our speed range curves, we now have a hypothetical horsepower of $800 - 92.6 = 707.4$ hp., and our hypothetical power loading $= \frac{12{,}000}{707.4} = 16.97$ lb./hp

Consulting curves again

Factors in column III (Table IV) apply to values of power loading to enter charts for Speed Range. However, after the speed range values have been obtained by using corrected hypothetical values of power and surface loading, these values of speed range should be added (to obtain high speeds) to the values of stalling speed that are obtained by using the *true* value of the surface loading. The real stalling speed, however, is obtained by using the corrected hypothetical value of surface loading.

In this table it is assumed that the power-altitude curves and the propeller efficiency (at high speed)—against altitude-curve—are as shown in Chart 1. It is also assumed that the wing section is similar to the R.A.F. 15 that the gap-chord ratio is between .95 and 1.1, and that, in no case, has any wing an opening in its center.

TABLE III

Altitude, f(abs. ceiling)	Altitude feet (15.53 lb./hp.)	Stalling speed m.p.h. Fig. 3 (8.75 lb./sq. ft.)	Speed range, m.p.h. (16.97 lb./hp.) Figs. 4, 5, 6, 7, 8, 9	High speed m.p.h.	Rate of climb, ft./min. (15.53 lb./hp.) Figs. 11 and 12	Time to climb/min. (15.53 lb./hp.) Figs. 14 and 15
0	0	53 5	51 5	105 0	644	0
250	3700	57 0	48 0	105 0	483	6 50
500	7400	61 0	42 0	103 0	322	15 36
750	11100	65 0	32 5	97 5	161	32 05
875	12950	67 0	25 0	92 0	80 5	47 05
1 000	14800	69 0	8 0	77 0	0	

Various Other Arrangements of Main Sustaining Surfaces

Table IV gives values of correction factors which may be used to obtain rough results in cases where the arrangement of main sustaining surfaces is other than biplane of aspect ratio—7. The method is to multiply the true loading values by the factors shown in order to obtain hypothetical loading values with which to enter the charts 1 to 15.

Factors in column I are applied to the values of surface loading (lb. per sq. ft.)

Factors in column II are applied to values of power loading (lb. per hp.—hp. of engine at sea level) to enter curves for Climb and Ceiling.

TABLE IV

	Correction Factors		
	I	II	III
Biplane—aspect ratio—5	1 035	1 028	1 010
Biplane—aspect ratio—9	970	945	985
Monoplane—aspect ratio—5	945	930	960
Monoplane—aspect ratio—7	880	900	960
Triplane—aspect ratio—7	1 035	1 010	1 015
Triplane—aspect ratio—9	960	955	1 000

Electrostatic Effects on Airships*

By Prof. Gordon S. Fulcher

Mixtures of hydrogen and air in proportions between certain limits may be exploded by a minute electric spark. Such mixtures may occur near any opening such as a valve of an airship from which hydrogen is being emitted into the air. And sparks may pass from one part of an airship to another or from the airship to a cloud, or to the ground, if electric charges are acquired which produce sufficient differences of potential. Also, when a balloon is being filled with hydrogen from cylinders, explosions sometimes occur which seem to be due to electric charges developed in the connecting tubes.

The problem is to determine the circumstances under which dangerous charges are acquired and then, if possible, to devise means either of preventing the accumulation of such charges or of rendering them harmless.

A survey of the literature on the subject gave very little reliable information; and the practices of other nations are so divergent as to be evidently untrustworthy as guides. Therefore an understanding of the electrostatic effects involved could only be obtained by experiment.

Experimental Results

Certain questions were formulated and then the answers given below were obtained as a result of experiments conducted at Princeton University and in the wind tunnel at the Navy Yard, Washington.

1. Is the balloon fabric used on airships a good insulator or not? *Answer.* The conductivity depends upon the moisture content of the surrounding air, but ordinary rubberized cotton fabrics are sufficiently good conductors, even when thoroughly dry, practically to equalize the potential of the whole balloon surface in about a minute. A sample of rubberized silk fabric was found to be a good insulator.

2. Are the hemp ropes used in suspending the car good insulators? *Answer.* No; from an electrostatic point of view they are good conductors.

3. Are rubber rings forming part of valve seats good insulators? *Answer.* Yes, when they are clean.

4. As a result of the electric field near the surface of the earth—from 50 to 200 volts per meter—the difference of potential between points at different heights above the surface may be very great. Will the sudden change of altitude of a conducting balloon cause it to acquire large charges? *Answer.* The charges induced on a conducting balloon, as can be shown by mathematical reasoning from the known laws of an electric field, depend upon the electric field in the region before the arrival of the balloon and upon charges induced on nearby conductors because of the disturbing effect of the balloon, therefore, the sudden transference of a balloon from a region of high potential to one of low potential will not change the charges on the balloon, provided the strength of the field is unchanged and provided the balloon is not brought near a conductor. The maximum field around an originally uncharged spherical balloon is three times the strength of the field into which it was brought, if no conductors are near, the maximum field between such a balloon and the flat surface of the ground just before contact is made is five times the original field, protuberances, especially sharp points, projecting from the balloon will have a greater field immediately around them than that stated above, increasing with the sharpness and the distance they project from the main surface of the balloon; but except during an electric storm and when a balloon approaches a highly charged cloud, the field around any balloon due to charges induced on it will be too weak to cause sparks.

5. May an airship acquire an electric charge as a result of being driven through the air at high speed? *Answer.* Yes, if the speed is sufficiently great, rubberized cotton fabrics become negatively charged, while rubberized silk fabrics become positively charged.

6. How does the effect depend upon the speed? *Answer.* It increases very rapidly with the speed, in fact, approximately as the sixteenth power of the speed, being about 50,000 times as great at 60 m.p.h. as at 30 m.p.h.

7. Does the effect depend upon the dust and moisture in the air? *Answer.* Yes, it depends chiefly if not wholly on the solid and liquid particles held in suspension in the air, dust and water particles seem about equally effective; with ordinary air the effect is small for speeds below 60 m.p.h., but in the case of smoke or mist large effects may be obtained with 40 m.p.h.

8. How does the effect depend upon the angle the fabric makes with the direction of its motion? *Answer.* It increases rapidly with the sine of the angle, approximately as the sixth power, so that the effect is practically zero when the fabric is moving tangentially, and is a maximum when the fabric is moving perpendicularly to its plane, the effect is therefore associated with impact rather than with skin friction.

9. Does the charge increase uniformly with the time? *Answer.* No; it increases less and less rapidly and tends to approach a limiting value.

10. Does a piece of fabric show signs of "fatigue"? *Answer.* Yes, in successive experiments with the same piece of fabric the effect was found to decrease progressively faster than could be due to the gradual decrease in the dust content of the air.

11. When a cylinder full of compressed hydrogen is insulated and then the gas is blown out through a copper tube, may the cylinder become charged? *Answer.* Yes.

12. How does the effect depend upon the rate of discharge? *Answer.* It increases rapidly with the rate, marked effects were obtained when the gas was discharged through a copper tube, 3/16 in. inside diameter at the rate of 4 cu. ft. per min.

13. Does the charge increase uniformly with the time? *Answer.* No, the cylinders tested became negatively charged at first, but soon the charge was neutralized and then became more and more positive, increasing more and more rapidly until high potentials were reached, the amount of condensed moisture in the gas also increases with the time since there is a rapid cooling of the valve and outlet tube by the cold expanded gas, this suggests that the effect is largely due to condensed moisture.

14. Can the effect be prevented by filtering out the dust and water droplets? *Answer.* Yes, by passing the gas through a rather large plug of glass wool, the speed of discharge is reduced somewhat, of course, but may still be sufficient to empty a cylinder in a few minutes.

15. Can hydrogen issue from the valve of an airship with sufficient speed to charge up the valve? *Answer.* According to computation the speed may be several hundred feet per second, which may charge up the valve if there is sufficient dust and moisture in the gas, no direct tests have been made as yet to determine whether in fact the valve of an airship may become charged.

16. Is a brush discharge as effective as a spark in exploding mixtures of hydrogen and air? *Answer:* Experiments made with explosive mixtures of hydrogen and oxygen showed that the soft brush or corona discharge such as is observed around an electrostatic influence machine when in operation is not effective in causing the explosion of such mixtures.

Conclusions: Dangers and Their Prevention

1. *Danger from sparks between various parts of an airship.* If the fabric and ropes are conducting, the only danger is that due to the rubber ring around the valve seat, which may become charged by the outflowing gas and cause a spark to pass through the gas to the valve. It would be a wise precaution to coat the rubber ring with graphite tallow or in some other way to make its surface conducting, and also to connect the valve and the seat by a wire firmly fastened to each. Glycerine and other petroleum products are non-conducting.

2. *Danger from sparks to ground on landing.* Since the airship may become highly charged as a result of motion through smoke or mist, the difference of potential between it and the earth as it descends may be sufficient to cause a spark. To avoid danger the landing rope should be a fairly good conductor—hemp rope will answer—and should be attached to the balloon in such a way as to insure a rapid discharge of the whole surface.

3. *Danger from sparks to a person after landing.* A spark may pass to a person approaching a valve either because the ballon or because the person is charged. In dry weather, especially, a person may easily become dangerously charged by friction. To avoid danger it would be wise to make it a rule to touch the fabric with a moistened hand at some distance from the valve before touching the valve itself.

4. *Danger from sparks to a charged cloud.* If the balloon chances to be in the path of a lightning flash between earth and cloud, it will probably be destroyed, but since the electric capacity of the balloon is small, a spark between it and a cloud can be prevented by relieving the electric tension by means of discharging points located as far as possible from explosive mixtures of gases. A sharp point or crown of points made of non-corroding metal, projecting above the dorsal fin of the airship and connected by wire to the steel framework of the fins, would eliminate most if not all of the danger.

In the case of kite balloons, it may be noted in passing, the danger of being struck by lightning is greatly increased by the telephonic connection to earth, discharging points would increase rather than diminish the danger; during a storm it would be better to insulate the balloon and cable by means of a solid rubber or sealing wax section of rope.

5. *Danger from brush discharge due to wireless.* Whether or not the brush discharge is dangerous depends upon whether it is a soft glow or is disruptive. Tests of the wireless outfit installed in an airship at Akron showed no signs of any brush discharge at all. At any rate, the energy is so small and the number of wires and points is so great that a dangerous brush discharge is extremely unlikely to occur. Hence the only danger arises from the possibility of sparks between two metal parts when contact happens to be poor. If, then, care is taken to see that a poor electrical connection between adjacent metal parts does not occur within five feet of the balloon, it would be no safer to insulate the car from the balloon than to use metal suspension wires throughout.

6. *Danger in connection with filling balloons from cylinders:* The danger arises from differences of potential between the fabric hose and the cylinder in case the hose blows off. The hose should be securely fastened to the metal pipe leading from the cylinder, and good electric connection should be assured by cleaning the surface of the metal pipe and by wetting the end of the hose in contact with the metal. In dry weather it would be well also to connect the cylinder to a metal bar driven into the ground through the top dry crust.*

Supplementary Report

General Statement. I still believe that (1) it is desirable that the outer surface of the balloon envelope should be conducting so that dangerous differences of potential between the various parts may be made impossible and so that the balloon may be rapidly discharged before landing, (2) that the inner surface of the envelope should also be conducting to prevent dangerous differences of potential from being produced by the friction of one surface upon another during inflation, (3) that, for similar reasons, the ropes suspending the car and especially the landing rope should also be conducting and that the latter should be so well connected to the envelope and other parts of the airship as to insure the rapid discharge of the airship before landing. The questions considered here are how sufficient conductivity may best be secured.

1. *Are cotton balloon fabrics sufficiently conducting?* The conductivity of cotton is associated with the fact that it is hygroscopic, and therefore depends upon the temperature and humidity of the surrounding atmosphere. Perfectly dry cotton cloth is a very good insulator, but when the relative humidity

* A report of the results of an investigation to determine the safety precautions in the design, construction and operation of airships necessary because of electrostatic effects, an investigation undertaken at the request of the Bureau of Construction and Repair, Navy Department.

* NOTE. A conducting fabric is preferable because it prevents dangerous differences of potential from arising between the various parts of the balloon because it enables the whole surface of the balloon to be rapidly discharged and because it prevents the accumulation of charges produced by the friction of one fold of fabric on another and when the ripping panel is used.

is over 60 per cent, cotton is a fairly good conductor. For the lowest humidities recorded for the Atlantic Seaboard the conductivity is still appreciable but so small that I cannot as yet state definitely that the conductivity would always be sufficient to eliminate all danger.

CONCLUSIONS. (1) Remembering that the airship is most likely to acquire frictional charges in going through mist or ice crystals, that is, when the humidity is necessarily high, I should conclude that the danger arising from the poor conductivity of the cotton outer ply of the envelope would be very slight.

(2) If a cotton inner ply is used, it may be kept sufficiently conducting by maintaining the humidity of the gas filling of the balloon up to 50 per cent or more.

(3) All danger could be eliminated by increasing the conductivity of the lower surface of the envelope around the valves and rope ends by adding a suitable coating.

II. *How may non-conducting surfaces be made conducting?* The following methods were considered:

(a) *Use of a hygroscopic salt* such as calcium chloride. The fatal objections to this method are (1) that such a salt is soluble in water and therefore easily washed off, and (2) that it is ineffective when the humidity is low.

(b) *Use of aluminum paint.* Since aluminum particles are each coated with the oxide, a mass of aluminum dust is almost non-conducting. Any varnish used to stick it on will further diminish the conductivity. The weight of the paint would be about 0.8 oz. per sq. yd. Other metallic paints, except gold, would be heavier.

(c) *Use of aluminum foil.* Aluminum foil can be obtained which weighs only .05 oz. per sq. yd. or about 3 lb. for an airship. The difficulty would be to stick it on durably. If sheets of aluminum foil about ten times as thick could be applied to the fabric while the rubber was still sticky, perhaps a durable metal coating could be secured which would not only be conducting and light in weight but would also have the valuable property of reflecting heat rays so as to prevent rapid changes of temperature of the balloon. The cost of the foil should be less than $0.25 a square yard. Gold foil would be more difficult to apply and more expensive.

(d) *Metallic coating sprayed on by the Schoop process.* Prof. Wilder D. Bancroft of Cornell called attention to this recently invented process in a letter to the National Research Council. It is described in the "Metallurgical and Chemical Engineering Magazine," vol. 8, p. 404, 1910; and vol. 11, p. 89, 1913. A sample is conducting and is coarse in structure. I have no doubt that a technique could be developed which would enable a thin conducting layer of aluminum to be sprayed on which would weigh not more than half an ounce per square yard.

(e) *Use of India Ink.* Two coats of commercial "waterproof" drawing ink applied without dilution make when dry a very durable and light conducting layer. Less ink is required on a smooth surface than on a rougher one. The weight added need be no more than 0.2 oz. per sq. yd. The cost of such ink is excessive, but doubtless a cheaper substitute can be found. Printer's ink would probably be as effective. The essential constituent is extremely finely ground carbon. As compared with an aluminum coating, carbon has the advantage of greater lightness but has the disadvantage of having a much greater absorbing power for heat.

CONCLUSION: Any one of the three methods last described would be effective from an electrostatic point of view. Until the technique of applying a metallic coating is perfected, it would probably be sufficient to paint the under side of airships, including the area around the valves and the places of attachment of the cords supporting the car, with some kind of carbon ink.

III. *Effect of the rubber insulation between the two plies of a balloon fabric.* When the two plies are conducting, they form with the rubber insulation a condenser of considerable capacity. A sample of cotton balloon fabric was tested and found able to withstand a difference of potential of over 10,000 volts between the two plies before a spark passed. But after a spark had once passed, the insulation was no longer intact and the difference of potential could not be raised to over a few hundred volts.

There are three cases to be considered. (1) If the two surfaces of a balloon fabric are conducting, the insulation will break down only at one point and more perforations will not result. (2) But if the two surfaces are insulating, sparks might pass at any point when the surfaces became charged up oppositely. (3) And if one layer is conducting while the other is not, the chance of sparking differences of potential arising would be greatly increased by induction effects. This is another argument for making both surfaces of the balloon fabric conducting.

Perhaps a rapid and sure method of testing balloon fabrics might be developed along these lines. The fabric might be passed between two metallic rollers charged to a potential of 5,000 volts by means of an electrostatic machine. A spark would pass through any leaky spot and thus indicate its location as somewhere along the line of contact of the rollers. The precise point could be determined by shifting one roller sideways. An index of the quality of the fabric could be obtained from the number of sparks per yard, whether or not the precise location of the leaky spots was determined.

If a cotton-silk fabric is used it would be better to make the cotton ply the inner surface as then its hygroscopic property can be used to keep it conducting. The silk ply will have to be made conducting by some one of the methods suggested above—at least in the neighborhood of the valves.

IV. *Ropes.* Hemp rope is hygroscopic and is conducting when the humidity is sufficient. For the ranges of temperature and humidities experienced on the Atlantic Coast, hemp rope is sufficiently conducting to be used in connecting various parts of the airship together. Of course it is not as good a conductor as a wire would be, and in the case of the landing rope, a wire rope would be preferable to insure a rapid discharge of the airship before landing. The landing rope should be fastened to a metal plate, one or two feet in diameter, fastened on the outside surface of envelope to insure good connection to surface layer. The conductivity of ropes can be greatly improved by soaking them in carbon ink.

V. *Loose joints.* It is particularly important that all loose joints should be such as to insure good electrical contact and prevent the possibility of a spark. Therefore no loose contact between iron and iron or between iron and anything else should be permitted as iron oxide is a good insulator. Aluminum or brass should be used.

VI. *The rubber lips of valves.* When hydrogen rushes past a rubber surface, there is the possibility of the surface becoming charged irrespective of how the metal supports of the rubber lips are connected. If the valve seat opposite the rubber lip is of the same kind of rubber, there is no danger, since both sides will become alike. But if the surface of the valve seat is conducting, a spark may pass from the lip to the seat through the issuing gas. If the gas is almost pure hydrogen, the danger is slight. If the gas is an explosive mixture, the danger is obviously greater. The surface of the rubber could be made conducting by painting with India ink. If the surface is made greasy with tallow or glycerine or vaseline, there is little danger of its becoming charged.

Book Review

THEORICO-PRACTICAL TEXT-BOOK FOR STUDENTS, by Benjamin M. Carmina. 172 pp., 92 figs. Macmillan Co., New York.

The author is Assistant Chief Instructor at a Y. M. C. A. Airplane Mechanic's School and has evidently written this small text-book with the requirements of such a school in view. In spite of the hybrid and irritating title he has produced a very creditable work.

The first two chapters on Theory of Flight are very clear, straightforward and easy for the beginner. The misstatements of several theoretical points in stability are conventional. Simplified methods of approach for stability inevitably involve these conventional misstatements, but no great harm is done thereby and a teacher of great ability and of a vigorously mathematical turn of mind will no doubt some day make the simplified theory conform with the truth.

The chapters dealing with Airplane Construction, Rigging and Maintenance are very good and will give a mechanic or anyone interested in the operation of an airplane a very sound introduction to the subject.

The Flight Hints are a very clear statement of the elements of stunt flying.

It cannot be said that the text-book is novel or likely to be a classic, but it is an honest piece of work and will serve a useful purpose among a large class of readers.

Course in Aerodynamics and Airplane Design

Part III.—Experimental Aeronautical Engineering

By Alexander Klemin

Technical Editor, Aviation and Aeronautical Engineering, Consulting Engineer, Aerial Mail Service; Consulting Aeronautical Engineer

Section 8. Wind Tunnel Experimentation—*Continued*

With a well constructed tunnel of a standard type and a good balance, the preliminary adjustments required are simple, though they require time and patience. The main operations are:

(a) *Alignment of Tunnel.*—The axis of the tunnel must be truly horizontal. To verify this a simple engineer's level mounted on a platform built on the floor of the building, opposite the mouth of the tunnel, can be used and sighted on the intersection of diagonal threads placed at intervals of five or six feet. By this means the distance of the center line of the tunnel above or below the horizontal can be estimated to ⅛ in., and supports raised or lowered, as required.

(b) *Alignment of Vertical Axes of Balance.*—To investigate whether the main axis of the balance is vertical or not, the torsion wire embodied in most balances can be readily employed.

The torsion wire is adjusted by means of a micrometer head until the cross-hairs are coincident. By setting up on the holding-down bolts the balance axis can be adjusted until placing a weight on either of the arms requires no further rotation of the torsion head to maintain coincidence of the cross-hairs. In such a case the axis of the balance is vertical.

(c) *Determination of Wind Direction in a Horizontal Plane.*—As a first approximation the wind is assumed parallel to the axis of the tunnel. A vertical flat plate is mounted on the balance arm and carefully set parallel to a line drawn on the floor of the tunnel in the direction of its axis. The plate is inclined to some 8 deg. to right and left of this position, and the transverse force measured on the balance. The observations are repeated at, say, 6 deg., and for a second plate to eliminate errors due to irregularities in the plate. If the transverse force on one side is greater than on the other an error is indicated in the wind direction. A new line is then drawn on the floor, correcting this error and observations for transverse force repeated. If in this second the difference in transverse forces is smaller, the second line is more nearly in the direction of the wind. If the error is unduly great the tunnel has to be reset to obtain a closer alignment.

(d) *Setting Arms of the Balance.*—Knowing the true direction of the wind, it is necessary to set the horizontal arms of the balance parallel and perpendicular to this direction. To do this the balance is simply rotated until the force recorded by the "drift" arm is equal for equal angles of the plate to right and left of the wind direction.

(e) *Adjustment of Velocity Gradient Across a Section of Tunnel.*—In any wind tunnel experiments it is important that the velocity of the air striking different parts of the model shall be the same. Consequently after precise methods for measuring velocity have been developed, as described in the previous issue, the cross-section of the tunnel must be explored to detect variations in velocity from point to point.

The procedure as employed at the calibration of the Massachusetts Institute of Technology tunnel was as follows:

The side plate was connected to a Chattock gage. One observer by regulating the motor field rheostat kept the velocity as nearly constant as possible. The Pitot tube was mounted on a standard and moved parallel to itself along vertical lines 6 in. apart. Great care was taken to point the tube in the axis of the wind. The Pitot tube was connected to the alcohol gage. A velocity reading was taken 6 in. by a second observer. After adjustment of the honeycomb farther into the tunnel a final calibration, as shown in Fig. 1, was obtained. It is seen that the variation in velocity over the useful part of the tunnel is from +1.1 to −1.2 per cent. Such a variation should be satisfactory for the average tunnel work.

(f) *Investigation of the Velocity Oscillations.*—It is generally taken for granted that if the steady velocity measurements are satisfactory no investigation of oscillatory effects is necessary. There are, however, in every tunnel pulsations corresponding to the beats of the propeller blades, and if there is reason to believe that these pulsations are serious a simple method of investigation is available. A concentric type of Pitot tube is connected to a pressure consisting of two pressure chambers separated by a diaphragm of thin metal. The center of the diaphragm is connected to a twisted strip,

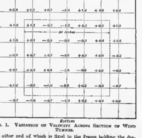

FIG. 1. VARIATION OF VELOCITY ACROSS SECTION OF WIND TUNNEL

the other end of which is fixed to the frame holding the diaphragm. The movements of the diaphragm produce large rotations of the strip and at the center of the strip a light mirror is attached. By an arrangement of a beam of light and a recording photographic flight velocity variations can be readily obtained.

Wind Tunnel Models

No accurate results can be expected from a wind-tunnel test unless the model is well and accurately constructed, and from the point of view of the airplane designer this is one of the most important aspects of wind tunnel work.

Model Aerofoils

In order that tests of different aerofoils may be compared definite standards are adopted. Thus the standard for a 4-in. tunnel is rectangular in plan form, 3-in. chord, 18-in. span, square ends.

Aerofoil models are made of brass, aluminum or wood. For small aerofoils, such as are used in the 4-ft. tunnel, where the maximum thickness is less than 12 per cent of the chord the aerofoil model should be of metal, for a wooden model cannot be made accurately enough. Thick sections such as propeller

sections should be made of wood. If made of metal they are likely to be excessively heavy and destroy the sensitivity of the balance. In a large wind tunnel the use of metal sections is inadvisable, since sufficient accuracy can here be secured in wood and the pivot point is no more resistant to loads than in the 4-in. tunnel balance.

Aluminum aerofoils, though harder to work, have been more satisfactory than the brass ones. Aluminum aerofoils are made either by casting a block roughly to correct shape and finishing by hand, or by filing and scraping from a solid block of sheet aluminum to a steel template. Unless the casting is exceptionally free from blowholes and free from warp the latter method is preferable. Brass aerofoils can be made by either method and may be cut very close to finish shape by machine instead of being cut entirely by hand. The surface of the aerofoil should be carefully polished to remove tool marks. On section of 3-in. chord an accuracy of .002 in. can be reached by careful work, and even .001 in. if extreme care is taken.

Wood is the most suitable material for thick sections like those on the inner half of a propeller blade. The most satisfactory method of making wooden aerofoils is to build up a

Fig. 2. Method for Making Model Aerofoils

rectangular block, laminated perpendicular to the chord to prevent warping, mark off the section on one end, cut the block along the span with a circular saw in a series of steps. (See Fig. 2.)

The depth of the cut is made such that it just touches the line at one corner, and the saw must be very sharp and run true. A milling machine may be used instead of a saw and can be set somewhat more accurately. The block is then smoothed and well shellacked. The wood used must be hard and fine grained, maple and mahogany being best adapted to the purpose.

For special tests such as biplane or triplane combinations, variation of aspect ratio, different rolling moment due to ailerons, sweepback or dihedral; different sizes of aerofoil are often necessary. Because of the difficulty of accurate construction, 2-in. is the smallest practical chord. If the total area of a single aerofoil does not equal 60 sq. in., it may be 24 or 25 in. long without seriously affecting the accuracy of the test. No general directions can be given for brackets or other fittings for holding models in combinations or for special tests. In general they should be made as light and small as possible to keep the total weight low and reduce interference effects.

2.—Models of Parts of Machines

First body models. The drag of a body is very small, so the model must be as large a scale as the tunnel will permit. If the model is to be tested at 0 deg. pitch and yaw only, it may be larger than if it is to be tested for cross wind force, etc., at angles of yaw, because at an angle of yaw the body swings across the tunnel and so obstructs it more to a greater extent. To be tested in yaw the largest size possible is 10 sq. in. projected area and 21 in. long (corresponding to 1/10 or 1/15 full size of a combat plane body). This is also the preferable size for any body model, but up to 15 sq. in. cross-section can be tested. Larger sizes obstruct such a portion of the tunnel that the actual velocity past the model is increased enough to affect the accuracy of the test.

For comparative tests of different bodies the models should be of the body alone, but if the model is to determine the body drag of a definite machine it may be fitted with motor exhaust pipes, chassis and empennage in order to help in the estimation of the effective drag of those parts. The bodies of the crew and guns should be included at least roughly.

Body models are invariably of wood and any wood suitable for pattern making may be used. The models are usually cut from a solid block, though often the two halves are made separately. If the model is large it must be hollowed out. For reference in the tunnel the center line and also the line of the propeller axis should be inscribed on the model. Men and other small additions or modifications may be made of wax or plasticene.

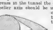

Fig. 3. Fairing of Wire Struts

Other parts of machines. Tests of chassis or tail planes alone are of little value because of interference. For calculating of performance the drag of struts, wires, fittings, etc., must be known. These members when made for test in the tunnel are subject to the same restrictions on projected area as those already specified for bodies. It is useless to test isolated examples of fittings, etc., which will normally rest against a large plane surface.

3.—Models of Complete Machines

The model should be carefully and accurately made, extreme care being required in assembling so that the wings are correctly located in regard to the body and have the correct gap and stagger. The model as usually tested consists of body, wings, struts, chassis complete, empennage, men and guns or other similar projection. No attempt is made to supply wires or fittings. Unless the model is to be tested with

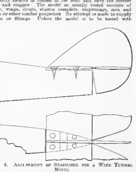

Fig. 4. Adjustment of Stabilizer for a Wind Tunnel Model

movable ailerons for rolling moments it is better to make the aileron in one piece with the wings.

Size.—For models of conventional biplanes or monoplanes the maximum size possible is governed by the span, which, for best results, should be under 18 in. However, if the wings have a large aspect ratio and a wider model is desirable, up to 21½-in. span may be used. These sizes correspond to scale of from 1/30 to 1/18 for usual planes.

Materials.—If the model is of an important plane the wing should be aluminum, bodies are always wood, tail surfaces either wood or metal, preferably the latter, wheels are usually wood, chassis struts either wood or metal.

Struts are generally made of round wire with no attempt at streamlining. The chief disadvantage of streamline struts is that delicate adjustment of the angles of the wings is impossible, since the threaded strut cannot be rotated less than a full turn. Fairly good results are obtained by the use of round wire struts, to the rear of which fairings are attached with a drop of solder after the adjustment of the wing angles is complete. (See Fig. 3.)

Struts should be threaded right-hand into the top wing and left-hand into the bottom. Between the planes the struts should be 1/16-in. in diameter if of round wire. With aluminum wings steel or brass bushings must be pressed into the wing in way of the struts, otherwise the threads will strip while the wings are being adjusted.

Adjustments.—The stabilizer should always be made adjustable. A very convenient method is shown in Fig. 4.

If a long series of tests is to be made machine screws should be used instead of wood screws, brass bushings being set into the body and tapped to take the screws.

If, as shown in the sketch, the fin is no longer than the stabilizer, it must be fastened rigidly to the latter and clearance left at the bottom of the rudder to allow for the adjustment of the stabilizer. Unless special rudder tests are desired the rudder should be made one piece with the fin. The elevator should be hinged to the stabilizer with soft copper wire 1/32-in. in diameter.

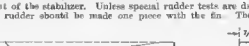

Fig. 5. Template for Construction of Stabilizer

This construction should be used also when movable rudders and ailerons are required.

If both surfaces of the horizontal tail members are convex a templet should be made which will fit snugly against one surface of the stabilizer and which will afford a flat surface, parallel to the chord of the stabilizer, to which the batten may be affixed for lining up that member. This templet should be ¼-inch wide. (Fig. 5.)

Theory of Dimensional Similarity Applied to Model Testing

In Part I, Section 3, it was pointed out that to compare forces for similar bodies but of different dimensions and under the action of different air velocities was a matter of some difficulty, and that a complex equation such as

$$R = el^2 V^2 f \frac{lV}{\gamma}$$

existed as an expression of the resistance.

The expression was then taken for granted, but it does not seem out of place to discuss here the elements of the theory of dimensional similarity, following very closely the excellent treatment of Cowley and Levy.

Every physical or dynamical conception can ultimately be expressed in terms of the three fundamental units or dimensions of length, time, and mass.

Speed, for instance, is distance divided by time, and if length is represented dimensionally by L, and time by T, the dimensions of speed will be L/T. Acceleration is a velocity divided by time, and consequently has the dimension L/T^2.

The quantities most commonly employed in aerodynamics can be in similar fashion demonstrated as having the following dimensions:

Quantity	*Symbol*	*Dimension*
Length	l	L
Time	t	T
Mass	m	M
Speed	v	L/T
Acceleration	a	L/T^2
Force	f	ML/T^2
Moment	M	ML^2/T^2
Density	e	M/L^3
Viscosity	μ	M/LT
Kinematic Viscosity	γ	L^2/T

If now a force f were expressed in terms of any other quantity, l, t, v, μ, etc. ... in any manner, the dimensions of the combination must, by the principle of homogeneity of dimensions be the same as those of force, namely ML/T^2.

In a great many cases in physics, and in aerodynamics, it is impossible to write down an exact expression connecting force, for instance, with a number of quantities, but it is possible to write down a dimensional equation, which sheds considerable light on the subject.

Consider that problem which is of most interest to us in aerodynamics. The force acted on a body immersed in air will depend on its geometric shape, its orientation with regard to the direction of motion, the velocity of the air, the density of the air, its viscosity and compressibility.

Instead of the viscosity, it is generally more convenient to use the kinematic viscosity $\gamma = \mu$. And similarly the speed C of sound waves in the fluid is fixed by the density and compressibility, so that conversely C together with e fixes the compressibility. The speeds with which we deal are so far below the speed of sound, that compressibility may very well be disregarded. So that the resistance of any body may be expressed in terms of t, v, l, e, μ and the shape and orientation of bodies. The two latter cannot be expressed by any symbol, nor is this necessary in the case of similar bodies similarly disposed relatively to the wind. Also for steady motion, t will not enter into the equation.

The resistance of a body, R, will therefore be represented by some expression $v^w l^x e^y \mu^z$ whose combined dimensions must be those of a force, that is ML/T^2. We can, substituting the dimensions of each of the terms, v, l, e, μ, write down the equations

$$\left(\frac{L}{T}\right)^w L^x \left(\frac{M}{L^3}\right)^y \left(\frac{M}{LT}\right)^z = \frac{M^{y+z} L^{w+x-3y-z}}{T^{w+z}} = \frac{T^2}{ML}$$

It follows by equating indices of the same quantities that $y + z = 1$, $w + y - z - 3y = 1$, $w + z = 2$, therefore $y = 1 - z$, $w = 2 - z$, $x = 2 - z$ and the expression becomes $v^{2-z} l^{2-z} e^{1-z} \mu^z = ev^2 l^2 \left(\frac{vle}{\mu}\right)^{-z} = ev^2l^2 \left(\frac{vl}{\gamma}\right)^{-z}$

There are not sufficient relationships to determine z and therefore

$$R = ev^2l^2 f\left(\frac{vl}{\gamma}\right)$$

where f is some unknown function of the most general form, $\frac{vl}{\gamma}$ which we call the Reynolds' number in Part I, section 3, must, since f is unknown, have the same value for the model as for the full size wing, if a direct comparison is to be made.

If v, l, γ, v_1, l_1, γ_1, are corresponding quantities for the model and for the full-sized machine

$$\frac{vl}{\gamma} = \frac{v_1 l_1}{\gamma}$$

since $\gamma_1 = \gamma$, for the same fluid no matter what the size of the resistant object.

Since in a 4-ft. tunnel the model is at most 1/24 of the full scale of the machine and the velocity also falls far short of the full speed of the airplane, it is impossible to realize conditions such that $vl = v_1 l_1$, nor on the other hand, although much investigation has been carried on in this direction, by test in the tunnel at varying speeds, and by comparing model tests with full flight tests, can it be said that our knowledge of the function $f\frac{lv}{\gamma}$ is very sound.

Correction to Full Scale from Wind Tunnel Tests

Besides the $\frac{vl}{\gamma}$ effect, minor inaccuracies have to be taken into consideration in wind tunnel tests. There may first of all be errors in the construction of the model itself, which are, however, avoidable by careful workmanship and subsequent careful adjustment. There is also the absolute impossibility of reproducing in the model, owing to their small scale, such parts as wires—which in the wind tunnel would have to be mere threads—radiators, fittings, control masts, chassis parts and other small parts. In the 8-ft. tunnel, of course, the possibilities in this respect are better than in the 4-ft. tunnel, and for accurate work very delicate and elaborate models can be constructed.

Corrections on the above score are not above the scope of an engineer well grounded in aerodynamics. It is when the

$f\ \frac{vl}{\nu}$ effect is considered that the greatest difficulties occur.

In Part I, Section 3, we have already considered briefly the subdivision of aerodynamic resistance into two parts, one being of the density or eddy-making nature, independent of viscosity and varying as the square of the linear dimensions and the viscosity squared, and the other varying with viscosity or more precisely with $\frac{vl}{\nu}$, or with constant viscosity as vl.

Not only will the latter variation depend on vl, but the subdivision of the two components will vary with the character of the resistance-producing body and its altitude relative to the wind. It seems impossible therefore that one general law for scale-size effect will be applicable to all wing sections or to wing-sections, strut-sections, wires, and other parts alike.

A great deal of data has been collected on the subject, and no doubt it will sooner or later be available for publication.

As the merest introductory hint, it may be said that corrections in the resistance of struts, streamline wires, and aerofoils at small angles of incidence will be very heavy for resistance with increasing values of vl. That for aerofoils at large angles of incidence K_y values will not vary so largely, and that K_y values will under no circumstances require as large corrections as K_x values.

The New York-Toronto Airplane Race

The international airplane race and handicap contest organized by the American Flying Club over the New York-Toronto-New York round-trip course was contested from Aug. 25 to 29 by fifty-four actual starters out of fifty-seven entrants. The competing airplanes represented a great variety of designs, which included the following types: DH-4, DH 9, USD-9A, Lepère, L-W-F, Vought VE-7, Curtiss Oriole, Avro Mono, SE-5, S V.A., Fokker, Curtiss JN-4H, JN-4D, Canadian Training, and Ericson Special.

The rules and regulations of this contest made of it a speed and handicap event. In the speed contest the machine making the return trip in the shortest time was to be declared winner, while in the handicap contest the standing of each airplane was worked out by application of a formula determining the ideal and actual performance of the contesting airplanes. By multiplying the machine's possible useful load by its stall air speed and dividing it by the horse power an index number indicating ideal performance was obtained. By multiplying its actual useful load by its actual speed in the race and dividing it by the horse power an index number indicating its actual performance was found. The ratio of the actual to the ideal gave the plane's performance percentage.

The round-trip course New York-Toronto was subdivided into eight legs, marked by control stations at Albany, N. Y., Syracuse, N. Y., and Buffalo, N. Y., where all contestants were compelled to land for refuelling "full" and inspection as to airworthiness. Stoppage at control stations was compulsory for 30 min., repairs were permissible, but where they exceeded in duration the time of compulsory stoppage, excess of time was counted against the contestant in his actual flight time. Delay due to atmospheric conditions which warranted the holding of contestants at control stations and the holding of machines due to nightfall was discounted.

The rules as well as the arrangements made at the various control stations worked out very satisfactorily, for despite very adverse weather conditions thirty two contestants finished the race, three of which were disqualified for infraction of flight rules. The race was run under the able direction of Chance M. Vought, chairman of the Contest Committee of the American Flying Club, with the effectual assistance of the Air Service, whose cooperation made of this contest the greatest airplane race ever held. This was made possible by Major-Gen. Charles T. Menoher, Director of Air Service, authorizing Army pilots to enter the contest *hors concours* and furnishing

Two SE-5s Starting from Roosevelt Field, Mineola, L. I.
Photo International

Major Schroeder, Winner of the Handicap, on the Vought VE-7
Photo Lavornick

personnel and material for ground work at the various control stations.

The speed contest was won by Lieut. B W Maynard, A.S., on a DH-4 with an actual flying time of 465¼ min for the 1040-mile round-trip course, while Major R W. Schroeder, A.S., flying a Vought VE-7, was declared winner of the handicap contest with a percentage of 107 8 The five leading machines in the speed contest were DH-4s, powered with the Liberty-12 engine, while Major Schroeder's VE-7 and the three contestants following him in handicap standing—all Curtiss JN-4Hs—were fitted with Hispano-Suiza engines.

The standing of the contestants who finished without disqualification appears with regard to handicap and speed in the following table:

Rel Finish	Plane	Pilot	Per Cent	Speed Finish
1	VE-7	Major R W. Schroeder	107.8	6
2	JN-4H	Major A. H. Gilkeson	104.6	18
3	JN-4H	Lieut. W. R. Taylor	96.8	20
4	JN-4H	Capt. H. B. Chandler	90.8	21
5	JN-4D	R. H. Depew	90.0	[illegible]
6	DH-4	Lieut. D. B. Gish	85.2	3
7	JN-4D	C. S. Jones	82.8	10
8	Oriole	Roland Rohlfs	82.0	16
9	DH-4	Lieut. B. W. Maynard	80.2	1
10	Can. Tr.	R. S. Moore	78.9	22
11	DH-4	Lieut. M. E. Plumb	77.0	9
12	DH-4	Lieut. Ben Adams	75.8	7
13	Can. Tr.	L. W. Bertaud	75.0	24
14	DH-4	Lieut. R. T. Mitkiff	73.3	11
15	DH-4	Col. G. C. Brandt	73.0	4
16	DH-4	Lieut. W. C. F. Brown	72.5	19
17	DH-4	Lieut. H. H. George	70.0	2
18	SE-5A	Lieut. Charles Coll	65.2	14
19	DH-4	Lieut. Ross Kirkpatrick	60.8	12
20	DH-4	Lieut. E. P. Honsinger	58.9	15
21	Le Père	Lieut. E. E. Logee	57.0	8
22	SE-5A	Col. H. B. Hartney	50.8	10
23	Fokker	Capt. C. W. Cook	48.8	17
24	Can. Tr.	G. A. Schiller	47.0	27
25	DH-4	Lieut. J. P. Roullot	46.0	8
26	JN-4H	Wallace Young	43.9	23
27	DH-4	Major J. W. Simons	37.8	28
28	Standard	O. E. Parmer	29.7	[illegible]
29	Fokker	Lieut.-Col. W. C. Barker	27.8	26

Although the persistently bad weather interfered to a certain extent with the race insofar as at times contestants were forced to stay at control stations for several hours while others lost their way in fog and rain storms and made forced landings, the New York-Toronto race was singularly free from serious accidents, in fact only four airplanes crashed to such extent as to render them unfit for further use, and two contestants, Capt F B Kindley and Lieut. A. B Crehore, suffered injuries owing to crashes, but no fatality marred the race Altogether the International Air Derby thoroughly fulfilled the object of its organizers, namely, to promote the science and sport of aviation by a public demonstration reflecting the safety and reliability of heavier-than-air craft in civil use.

Inactive R. M. A.'s Fly

The Commanding Officer at any Air Service station where flying is authorized may permit qualified Reserve Military Aviators, who are in inactive status, to take such flights in Government aircraft as he deems advisable. Cross-country flights will not be made under this authority and no interference with the regular training or the operation of a station will be permitted.

Before exercising the authority given them in preceding paragraph, Commanding Officers of Air Service stations will be held responsible that the following conditions have been fulfilled

(a) That individuals applying for such permission have fully and completely identified themselves—documentary evidence being required when necessary.

(b) That such individuals have demonstrated to the Flight Surgeon that their physical condition is satisfactory for solo flights.

(c) That no applicant is permitted to fly solo until he has been reported by a qualified instructor as competent to do so after an actual test in the air.

The foregoing instructions have been found necessary as a result of the experience gained to date relative to flying engaged in under authority of Orders No. 30, O. D. A. S., 1919, which has been rescinded by this order. Commanding Officers are directed to observe the spirit as well as the letter of these instructions to the end that Government property may not be needlessly destroyed nor the lives of over-enthusiastic pilots in poor physical condition, or whose flying efficiency has been lowered by too long an absence from flying, be needlessly endangered.

Major Springs on a L-W-F
Photo Lavornick

Bert Acosta on a Curtiss Oriole
Photo Lavornick

Air Transport in Great Britain

Passenger Airplane of the Handley-Page Transport Co. Employed in a Tri-Weekly Service Between London, Paris and Brussels
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Interior View of the Passenger Cabin of the Handley-Page Transport Airplane—a Converted 0-400 Bomber
(c) *Western Newspaper Union*

The Stanford University Aerodynamic Laboratory

By E. J. Baughman

The first Stanford University aerodynamic laboratory was installed during the fall and winter of 1916-1917, through the efforts of Professor W. F. Durand. The immediate purpose in view was the provision of an equipment for carrying on an investigation on air propellers. During the years 1917-1918 over one hundred model propellers were tested for the National Advisory Committee for Aeronautics and the aviation branch of the United States Army. During the latter part of the year 1918 the laboratory was torn down to permit

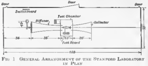

Fig. 1 General Arrangement of the Stanford Laboratory in Plan

the building of an electric substation. The Board of Trustees of the University seeing the practicability and necessity of the work carried on, established a fund for the construction of a new laboratory. This has but recently been completed, and it contains one of the largest wind tunnels, with propeller testing equipment in the United States. The laboratory and its equipment was designed by Professor E. P. Lesley of the mechanical engineering department of the university.

The building, which is situated on the university grounds, joining the engineering shops, is 150 ft. long, 50 ft. wide, and 22 ft. high to the eaves; it is a one story frame building, the

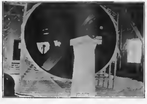

Fig. 2 Diffuser End of the Tunnel with 8-Bladed Fan

sides being covered with sheet boarding, and the roof shingled. The interior is well lighted by large windows placed in all four sides. The roof is supported by an arrangement of bracing similar to that used in hip roof barns, thus the whole interior of approximately 170,000 cu. ft. is left clear, with the exception of the space occupied by the wind tunnel, for the circulation of air. The laboratory has a concrete floor which is made exceptionally thick under the reinforced concrete fan pedestal and the driving motor.

The diffuser end of the wind tunnel is 34 ft. from one end of the building and as the tunnel is 73 ft. long, over 40 ft. of space is left at the opposite end of the laboratory. This space serves as a reservoir from which a uniform air stream can be pulled into the collector by the fan in the end of the diffuser. A diagrammatic sketch of the laboratory is shown in Fig. 1.

Before building the new wind tunnel many types were considered. The Eiffel type used in the first Stanford aerodynamic laboratory, being of round section, was thought superior for propeller testing to the square section type used in the National Physical laboratory in Teddington, England, or the closed circuit type used by Col. Crocco in Italy.

The new wind tunnel consists of three parts, the diffuser and collector, separated by the test chamber. The tunnel with its narrowing throat acts as a venturi tube. The pressure head at the end of the collector is changed to a velocity head in the test chamber, this then returning to a pressure head at

Fig. 3. Looking Into the Tunnel from the Collector End

the fan end of the diffuser. Thus a maximum velocity of over 80 m.p.h. is obtained in the experiment room through a relatively low expenditure of power applied to the fan. The air in circulating at a low velocity from the diffuser to the collector is allowed to cool in sharp contrast to the usual heating of the air in the closed circuit type tunnel.

The tunnel and the test chamber are built of kiln dried matched Oregon fir. The method of laying out the curves for the collector and diffuser is completely described in report No. 14 of the National Advisory Committee for Aeronautics.

Fig. 2 shows the diffuser end of the tunnel containing the eight blade cedar fan. The fan is 14 ft. 10 in. in diameter, having an .8 pitch ratio, and is of the form and section of propeller No. 2 in the N. A. C. A. report No. 14. The fan is driven through a belt connection by a 100 hp. variable speed D. C. motor. The motor controls are located in the testing chamber. The current supplied to the motor is received from a rotary converter set, and thus a constant and uniform supply of power is insured.

Fig 3 shows the tunnel, looking in the collector end. The fan situated on the opposite end of the tunnel and the propeller testing stand in the test chamber are plainly visible. A honeycomb baffle to straighten out the flow will be placed in the delivery end of the collector as soon as completed

Because of the reduced pressure in the experiment room while running tests, an air lock was provided for entry and exit. The room is made practically air tight with the exception

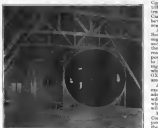

Fig. 4. Experiment Room, Seen from the Collector End

of the tunnel openings. The windows are sealed in special casings, and the sides and top of the room are specially braced. Fig 4 shows the side of the experiment room looking from the collector end.

The propeller testing stand is the same as used in the old air tunnel and consists principally of an apparatus for weighing the thrust of the model propeller on a suitable scale arrangement, a torsion dynamometer for measuring the power absorbed by the propeller from the driving motor, a revolution counter, and a air-speed meter.*

Plans are under way for the construction of a new testing rig which will use the principle embodied in the Sprague dynamometer for measuring torque, and which will be driven by a 20 hp motor, making it possible to test propellers of 5 to 6 ft. in diameter Arrangements are also being made for the building of an aerodynamic balance for the testing of model aerofoils and models of complete airplanes

Radio Training

A six months' radio course requiring at least three hours a day has been initiated by the Army Air Service in accordance with plans for vocational and educational training for the purpose of further training men attached to depot and service squadrons for radio duty It aims to prepare the men with the proper qualifications for duty as radio operator mechanics and mechanic-operators until such a time as a radio training center is established.

The qualifications necessary for the personnel to be assigned to duty with field radio detachments are not difficult and embrace reading buzzer code for ten minutes, reading blinker code, sending code for ten minutes, examination in elementary electricity, erection of field stations, etc. The course will of necessity be very practical, only such theoretical grounding being given as is absolutely essential to grasping the subject under consideration

Equipment Warehouses

Owners of airplanes, as well as manufacturers and those individuals and concerns who are building experimental machines, will be interested in the announcement of the opening of warehouses in New York and Chicago for the distribution of high grade aircraft parts and equipment.

This new concern, the Aircraft Materials & Equipment Corp., has completed arrangements whereby they become distributors in the United States of spare parts for Canadian training planes, the machines used by the Royal Air Force in Canada for training purposes and of which several hundreds have been sold for commercial purposes throughout the country.

A large warehouse has been leased in New York at 1409 Sedgewick Avenue, where a complete stock of parts for engines as well as airplanes will be kept on hand at all times and a plan has been worked out whereby parts will be shipped the same day the order is received This is done for the reason that these planes are used strictly for commercial purposes and owners must secure parts in the minimum of time to keep the planes operating every day. To facilitate ordering, a comprehensive parts catalogue has been published in which is listed every part of the Canadian Training plane and OX-5 engine, both as an individual unit and also in the assembly in which it belongs

A branch warehouse has been opened in Chicago with the executive office in the Westminster Building, and as soon as adequate arrangements can be made an additional warehouse will be opened in San Francisco, so that owners of airplanes whether they live in New York or a small town in Arizona, will be assured of efficient supply service

M. W. Hanks, president of Aircraft Materials & Equipment Corp., has had wide and varied experience in all matters pertaining to aircraft work He was in Washington during the war where he was in charge of aircraft specifications, Bureau of Construction and Repair, Navy Department. Before the war he was Standards Manager of the Society of Automotive Engineers and prior to that time was Western manager of the automobile equipment department for the Westinghouse Electric and Manufacturing Company

The parts book mentioned above will be mailed without cost to those interested.

European Air Lines

A number of interesting announcements concerning the establishment of air lines in Europe have been made in connection with the Amsterdam Aeronautical Exposition held last month.

Vickers, Ltd., announced a combination of passenger and mail services which will help form the links of an aerial chain from England and France through Central Europe. The first service will be between London and Flushing by means of a Vickers flying boat From Flushing, and in connection with the London service, there will be services all over Holland by Vickers-Vimy commercial airplanes to Rotterdam, The Hague, Mastricht, Amsterdam and Northern Holland. There will also be a circuit from London to Paris, Brussels and The Hague.

Another service in the preliminary stages will be started via Arnheim, Germany, to Central Europe, probably connecting with Berlin There is a possibility that this service will connect with a Zeppelin service operating since last August from Berlin to Friedrichshafen, connecting with Swiss steamboats on Lake Constance and landing at Munich on the way. For this a new type of commercial airship built since the war will be used

The capital for the network of aviation services will be $5,000,000, partly Vickers' capital and partly taken in Holland. There is little Dutch competition, as the Dutch have practically no aircraft factories. They had no material for this purpose during the war and even most of the machines for the Dutch army came from Germany, the parts being put together here.

Complete organization of the new plans is expected to be ready at the beginning of 1920. Handley-Page, Ltd, has announced regular service between Amsterdam and London, Paris and Brussels (see p. 182)

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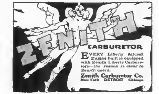

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